

Appendix A: Hazard Identification and Assessment

A. INTRODUCTION

Prior to updating the Hazard Mitigation Plan, it is vital to identify and reassess the hazards that could potentially affect the Town of Knightdale. According to FEMA and NCEM criteria for the development and updating of a Hazard Mitigation Plan, the following hazards must be addressed: Dam Failure, Drought/Heat Wave, Earthquakes, Flooding, Hurricane/Coastal Storms, Landslides/Debris Flow, Tornadoes/Severe Thunderstorms, Wildfires and Severe Winter Weather. Although Nor'easters affect North Carolina, most of the damage occurs in the form of beach erosion. Inland effects of Nor'easters are nearly identical to those of a Severe Winter Storm and are addressed as such.

The hazards were ranked according to the potential damage they could cause. The ranking of each hazard appears in the chart below.

Table A-1 - Hazard Ranking

Hazard	Rank	Comments
Dam Failure	Low	Not addressed in plan
Drought/Heat Wave	Moderate	Addressed in plan
Earthquakes	Low	Not addressed in plan
Flooding	Moderate	Addressed in plan
Hurricanes/Coastal Storms	Moderate	Addressed in plan
Landslides/Debris Flow	Very Low	Not addressed in plan
Tornadoes/Severe Thunderstorms	Moderate	Addressed in plan
Wildfires	Low	Not addressed in plan
Severe Winter Weather	Moderate	Addressed in plan

Of the nine (9) natural hazards identified, five (5) were given a composite ranking of moderate based on each hazard's likelihood of occurrence, likely magnitude, and potential impact. These hazards have impacted the Town of Knightdale in the past, and impacts from these hazards are expected to continue. These hazards, drought/heat wave, flooding, hurricanes/coastal storms, tornadoes/severe thunderstorms, and severe winter weather are addressed in the Hazard Mitigation Plan.



B. METHODOLOGY

The identification and assessment were performed according to the following steps:

- describe potential hazard,
- predict likelihood of occurrence,
- predict likely magnitude of hazard, and
- predict possible impacts from hazard.

A composite ranking was determined for each hazard upon completion of the assessment. This ranking was based on the hazard's likelihood of occurrence, likely magnitude, and potential impact.

1. Hazard Description

The description of each hazard includes a history of the hazard's presence in Knightdale. Hazard data for Wake County obtained from the National Climatic Data Center (NCDC), local historical evidence, and interviews with Town staff were used in the descriptions of the hazards. In addition, North Carolina Emergency Management (NCEM) categorized vulnerability for nine (9) hazards for each county. Local historical information was solicited from the public.

2. Likelihood of Occurrence

The likelihood of occurrence of each hazard, based on regional data and local historical evidence, was predicted in accordance with the following chart:

Table A-2 - Likelihood Based on Frequency of Occurrence

Likelihood	Frequency of Occurrence
Highly Likely	Near 100% probability in the next year
Likely	Between 10 and 100% probability in the next year, or at least one chance in the next 10 years
Possible	Between 1 and 10% probability in the next year, or at least one chance in the next 100 years
Unlikely	Less than 1% probability in the next year, or less than one chance in the next 100 years

Source: Keeping Natural Hazards From Becoming Disasters, A Mitigation Planning Guidebook for Local Governments, NCEM, 2003.



3. Magnitude

The magnitude or intensity is a function of the amount of damage a hazard can cause. The magnitude or intensity of each hazard was estimated in accordance with standardized rating scales or general terms. Standardized rating scales applicable to some of the hazards are found in the individual hazard descriptions. Magnitude or intensity for hazards without standardized rating scales was estimated according to the table on the following page.

Table A-3 - Description of Magnitude

Magnitude	Description
Mild	Affects less than 10% of the Town and its ETJ
Moderate	Affects between 10% and 40% of the Town and its ETJ
Severe	Affects more than 40% of the Town and its ETJ

4. Level of Impact

The level of impact takes into account the impact on humans, impact on critical facilities, and impact on property. The level of impact was estimated in accordance with the following table:

Table A-4 - Level of Impact Based on Area, Injuries, Effect on Critical Facilities, and Property Damage

Level	Area Affected	Impact
Catastrophic	More than 50%	One or more deaths Complete shutdown of critical facilities for 30 days or more More than 50% of property is severely damaged
Critical	25 to 50%	Multiple severe injuries Complete shutdown of critical facilities for at least 2 weeks More than 25% of property is severely damaged
Limited	10 to 25%	Some injuries Complete shutdown of critical facilities for more than one week More than 10% of property is severely damaged
Negligible	Less than 10%	Minor injuries Minimal quality-of-life impact Shutdown of critical facilities and services for 24 hours or less Less than 10% of property is severely damaged

Source: *Keeping Natural Hazards From Becoming Disasters, A Mitigation Planning Guidebook for Local Governments*, NCEM, 2003



5. Composite Ranking

A composite ranking was determined for each hazard following completion of the assessments. This ranking was based on the hazard's likelihood of occurrence, likely magnitude, and potential impact. Hazards with higher composite rankings and therefore, higher potential for damage, are addressed in the Hazard Mitigation Plan.

Table A-5 - Hazard Ranking Chart

Likelihood↓/Impact→	Catastrophic	Critical	Limited	Negligible
Highly Likely	Very High	High	High	Moderate
Likely	Very High	High	Moderate	Low
Possible	High	Moderate	Low	Low
Unlikely	Low	Low	Very Low	Very Low

C. IDENTIFICATION AND ASSESSMENT OF HAZARDS

1. Dam Failure

Although dam failure is a technological hazard, the occurrences of natural hazards such as severe storms and hurricanes that cause flooding are frequently the cause of dam failure. Any dam whose failure could potentially result in the loss of life is classified as high hazard. Wake County currently has 389 dams under the jurisdiction of the Department of Environment and Health, Dam Safety Division. Of those 389, 132 are classified as high hazard according to the 2008 Dam Inventory for the state. According to Town records, only one (1) high hazard dam is located within Knightdale's jurisdiction.

According to dam safety records, no dams in Knightdale have failed, but records for Wake County show that two (2) dams have been breached since 2004. Dam failure is definitely possible, but it is unlikely.

The failure of a dam would result in damage only to the area immediately surrounding and downstream of the dam. Failure of any of the dams would result in damage to less than 10% of the Town. As a result, the magnitude or intensity of damage is categorized as mild.



A dam failure would likely affect less than 10% of the town and result in minimal damages to property, critical facilities, and quality of life and minor injuries. As a result, the level of impact is categorized as negligible.

Based on probability of occurrence, magnitude, and level of impact, the hazard ranking of dam/levee failure is low. Dam/levee failure is not addressed by the Hazard Mitigation Plan.

2. Drought/Heat Wave

According to the National Oceanic and Atmospheric Administration (NOAA), a drought is a period of abnormally dry weather that persists long enough to produce a serious hydrologic imbalance (for example crop damage, water supply shortage, etc.). The severity of the drought depends upon the degree of moisture deficiency, the duration of the drought, and the size of the affected area.

There are four different types of droughts:

Meteorological - when precipitation is lower than normal for a specific location.

Agricultural - when the soil moisture content does not meet the needs of a particular crop.

Hydrological - when surface and subsurface water supplies are below normal.

Socioeconomic - when physical water shortage begins to affect people.

Meteorologists predict drought by monitoring precipitation compared to historically established normal data. Several drought indices are used to categorize the severity of the drought. The Palmer Drought Severity Index has been widely used by the U.S. Department of Agriculture to determine when to grant emergency drought assistance. It predicts drought by assessing soil moisture. The National Drought Mitigation Center is using a newer index, the Standardized Precipitation Index, to monitor moisture supply conditions. It is less complex than the Palmer scale and its ability to assess drought conditions for different time scales allows for earlier prediction of drought.

According to FEMA, heat wave is characterized by temperatures 10 degrees or more above the average high temperature for the region that last for several weeks. The National Weather Service (NWS) has devised the Heat Index to



describe how hot it actually feels. The Heat Index takes into account the effect of relative humidity as well as the air temperature. Extreme heat can result in serious health conditions. They include:

- Heat cramps: characterized by painful spasms usually in muscles of legs and abdomen and heavy sweating.
- Heat exhaustion: characterized by heavy sweating, weakness, clammy and cold skin, fainting and vomiting.
- Heat stroke or sun stroke: characterized by high body temperature (106 degrees F or higher), hot dry skin, rapid and strong pulse, and possible unconsciousness.

The following table lists the danger categories for heat disorders as a function of heat index.

Table A-6 - Danger Categories for Heat Disorders

Danger Category	Heat Index	Possible Heat Disorders
Extreme danger	130F or higher	Heat stroke or sun stroke likely.
Danger	105 – 129F	Sunstroke, muscle cramps, heat exhaustion likely. Heat stroke possible with prolonged exposure.
Extreme caution	90 – 104 F	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure.
Caution	80-89 F	Fatigue possible with prolonged exposure.

Source: NWS Southern Region Headquarters Heat Wave website, National Weather Service

Review of historical data from the NCDC showed that North Carolina has experienced several droughts and heat waves in recent history. Descriptions of these events follow. The present worth cost of damages is included in parentheses.

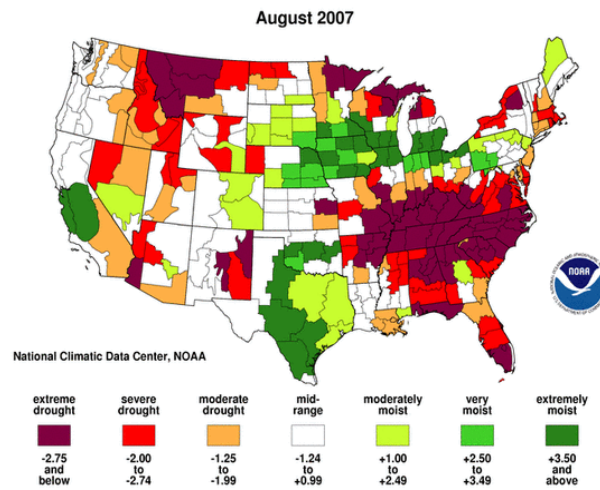
- Drought/Heat Wave June-September 1980. Affected central and eastern U.S. Damages/costs to agriculture and related industries estimated to be \$20.0 (48.4) billion. Number of deaths estimated to be 10,000 (includes heat stress-related deaths).



- Southeast Drought/Heat Wave-Summer 1986. Severe summer drought in parts of the southeastern U.S. Damages/costs to agriculture estimated to be \$1.0-\$1.5 (1.8-2.6) billion. Number of deaths estimated to be 100.
- Drought/Heat Wave-Summer 1988. Drought in central and eastern U.S. Damages/costs to agriculture and related industries estimated at \$40.0 (61.6) billion. Number of deaths estimated to be 5,000 to 10,000 deaths (includes heat stress-related deaths).
- Drought/Heat Wave-Summer 1993. Affected Southeastern U.S. Damages/costs to agriculture estimated at \$1.0 (1.3) billion. Number of deaths estimated to be at least 16. North Carolina had hottest July on record, 2nd hottest summer on record, and 2nd driest summer on record (records date back to 1895). Disaster areas declared for 89 of 100 counties. Crop losses estimated at \$165 million in North Carolina.
- Southern Drought/Heat Wave-Summer 1998. Severe drought and heat wave from Texas/Oklahoma eastward to the Carolinas. Damages/costs to agriculture and ranching estimated at \$6.0-\$9.0 billion (6.6-9.9). Number of deaths estimated to be at least 200. According to Palmer Scale, central North Carolina experienced a moderate drought. July and August were also hotter than normal for North Carolina.
- Drought/Heat Wave Spring-Summer 2000. Severe drought and persistent heat over south-central and southeastern states. Damages/costs to agriculture and related industries estimated at over \$4.0 (4.2) billion. Number of deaths estimated at 140 nationwide. According to Palmer scale, central North Carolina experienced a moderate drought.
- Widespread Drought Spring through early Fall 2002. Moderate to Extreme drought over large portions of 30 states, including the western states, the Great Plains, and much of the eastern U.S. Damages/costs estimated at over \$10.0 billion. No deaths reported. For the month of July, 39% of the contiguous U.S. experienced moderate or severe drought. All of NC experienced drought; drought in piedmont was extreme, in mountains was severe, and in coastal plain was severe or moderate.
- Great Plains and Eastern Drought: Entire year 2007 (see following graphic). Severe drought with periods of extreme heat over most of the southeast and portions of the Great Plains, Ohio Valley, and Great Lakes area, resulting in major reductions in crop yields, along with very low stream-flows and lake levels. Includes states of ND, SD, NE, KS, OK, TX, MN, WI, IA,



MO, AR, LA, MS, AL, GA, NC, SC, FL, TN, VA, WV, KY, IN, IL, OH, MI, PA, NY.
Preliminary estimate of well over \$5.0 billion in damage/costs; some deaths reported due to heat but not beyond typical annual averages.



According to NCDC data, there have been eight (8) moderate to severe droughts/heat waves in North Carolina since 1980. As a result, drought/heat wave is characterized as likely for Knightdale.

Drought/heat wave typically affects large areas such as entire states or whole regions of the country. As a result, the occurrence of a severe drought/heat wave could affect a large area of the Town, therefore the magnitude or intensity of damage is categorized as moderate.

Although a drought/heat wave would likely affect a large portion of the Town, the impact to critical facilities is expected to be limited. Impact to property, particularly agricultural impacts, could be considerable but would not be expected to affect more than 25% of the Town. For an extended drought/heat wave, minor injuries could be expected as well as considerable restrictions being place on the use of potable water. As a result, the impact due to drought/heat wave could range from limited to negligible.

Based on probability of occurrence, magnitude, and level of impact, the hazard ranking of drought/heat wave is moderate. Typically, drought/heat wave mitigation is handled on a large scale by state agencies; however, within the last few years the City of Raleigh Public Utilities Department has merged its water distribution and sewage collection systems with the Town of Knightdale's systems as well as several other northeastern, eastern and southeastern Wake County towns. Consequently, the Town of Knightdale through the City of Raleigh can



undertake some measures to mitigate the effects of an extended drought; therefore, drought and heat waves are addressed in the Hazard Mitigation Plan.

3. Earthquakes

FEMA defines an earthquake as a sudden, rapid shaking of the Earth caused by the breaking and shifting of rock beneath the Earth's surface. This shaking can cause buildings and bridges to collapse; disrupt gas, electric, and phone service; and sometimes trigger landslides, avalanches, flash floods, fires, and huge, destructive ocean waves (tsunamis). Buildings with foundations resting on unconsolidated landfills, old waterways, or other unstable soil are most at risk. Buildings or trailers and manufactured homes not tied to a reinforced foundation anchored to the ground are also at risk since they can be shaken off their mountings during an earthquake. When an earthquake occurs in a populated area, it may cause deaths and injuries and extensive property damage. Earthquakes can occur at any time of the year.

Earthquakes are measured in terms of their magnitude and intensity. Magnitude is measured using the Richter Scale, an open-ended logarithmic scale that describes the energy release of an earthquake through a measure of shock wave amplitude. Intensity is most commonly measured using the Modified Mercalli Intensity (MMI) Scale. It is a 12-level scale based on direct and indirect measurements of seismic effects.

Table A-7 - Modified Mercalli Scale of Earthquake Intensity

Scale	Intensity	Description of Effects	Maximum Acceleration (mm/sec)	Corresponding Richter Scale
I	Instrumental	Detected only on seismographs	<10	
II	Feeble	Some people feel it	<25	<4.2
III	Slight	Felt by people resting; like a truck rumbling by	<50	
IV	Moderate	Felt by people walking	<100	

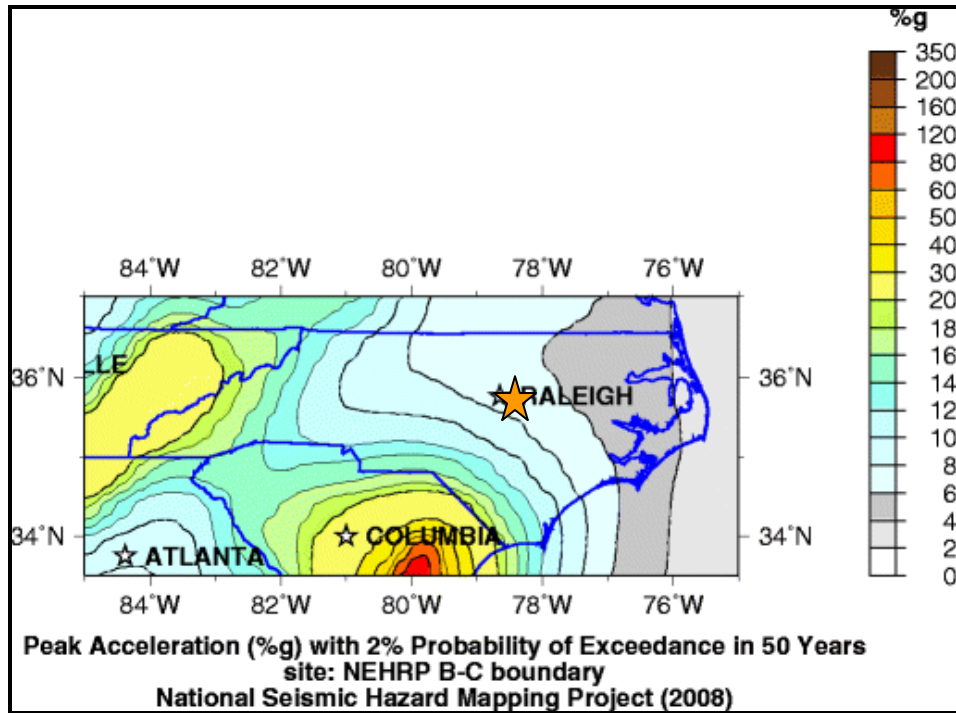


V	Slightly Strong	Sleepers awake; church bells ring	<250	<4.8
VI	Strong	Trees sway; suspended objects swing, objects fall off shelves	<500	<5.4
VII	Very Strong	Mild alarm; walls crack; plaster falls	<1000	<6.1
VIII	Destructive	Moving cars uncontrollable; masonry fractures, poorly constructed buildings damaged	<2500	
IX	Ruinous	Some houses collapse; ground cracks; pipes break open	<5000	<6.9
X	Disastrous	Ground cracks profusely; many buildings destroyed; liquefaction and landslides widespread	<7500	<7.3
XI	Very Disastrous	Most buildings and bridges collapse; roads, railways, pipes and cables destroyed; general triggering of other hazards	<9800	<8.1
XII	Catastrophic	Total destruction; trees fall; ground rises and falls in waves	>9800	>8.1

Source: Keeping Natural Hazards From Becoming Disasters, A Mitigation Planning Guidebook for Local Governments, NCEM, 2003.

Approximately two-thirds of North Carolina is subject to earthquakes with the western and southeast region most vulnerable to a very damaging earthquake (see following map). Knightdale only maintains a 2% probably of seeing a peak acceleration of six (6) to eight (8) millimeters/second from an earthquake in the next 50 years which is the lowest scale of "1" that will not be felt, but only recorded on a seismograph.



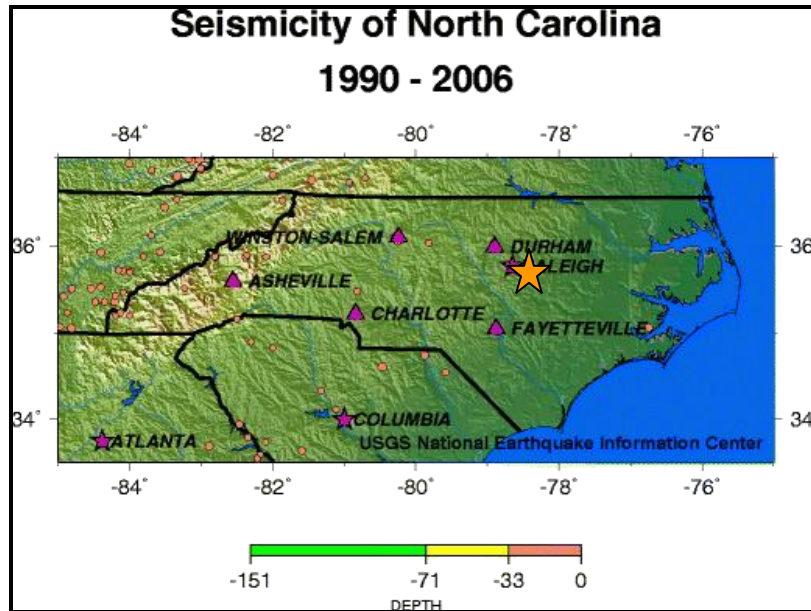


The most notable earthquake in the Carolinas was the Charleston quake of 1886 which was felt over 1000 miles away in Illinois. This earthquake caused considerable damage in both Charlotte and Raleigh. Other notable earthquakes that have caused damage in North Carolina occurred in 1735 (centered in Bath), 1811 (centered near New Madrid, Missouri), and 1916 (centered in Waynesville). Subsequent minor earthquakes have caused damage in North Carolina in 1926, 1928, 1957, 1959, 1971, 1973 and 1976.

According to the North Carolina Geological Survey (NCGS), one known major fault is located in southwestern Wake County. This fault identified by NCGS is described as ancient and inactive. NCEM has categorized the risk for earthquakes in Wake County as low.

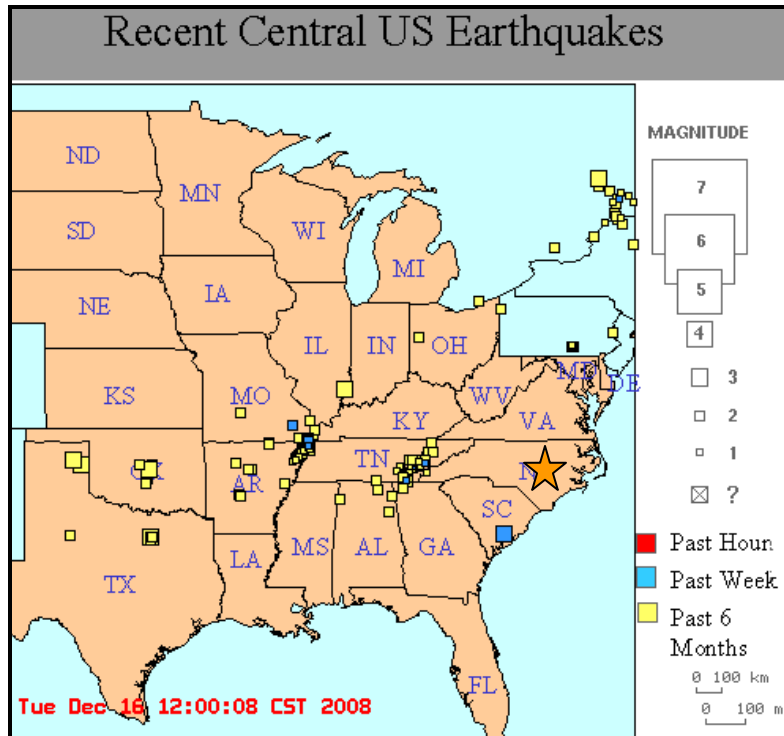
According to a review of USGS earthquake data between 1698 and 2008, no earthquakes centered near Knightdale have been recorded. More recently, between 1990 and 2006, the closest earthquake occurred near Greensboro, but was very minor and shallow (see following seismicity map).





A review of specific data in the previous 6 months as of December 16, 2008 (see following graphic) revealed that the most recent earthquake activity in North Carolina was a magnitude 1.9 quake near Robbinsville, NC on June 21, 2008—over 300 miles away. The closest out of state occurrence was a magnitude 3.6 near Summerville, in the southern part of South Carolina on December 16, 2008. The occurrence of an earthquake is categorized as unlikely. Earthquakes are not addressed by the Hazard Mitigation Plan.





Courtesy: University of Memphis Center for Earthquake Research & Information

Though unlikely, the occurrence of an earthquake centered near Knightdale could result in damage to a significant portion of the Town. As a result, the magnitude or intensity of damage is categorized as severe.

An earthquake centered near Knightdale could likely affect a significant portion of the town and result in serious injuries and property damage and disruption of critical services for a period of time. As a result, the level of impact is categorized as critical.

Based on probability of occurrence, magnitude, and level of impact, the hazard ranking of an earthquake is low. Earthquakes are not addressed in the Hazard Mitigation Plan.

4. Flooding

According to the National Oceanic and Atmospheric Administration (NOAA), flooding is a localized hazard that is generally the result of excessive precipitation. Floods can be generally considered in two categories: flash floods, the product of heavy localized precipitation in a short time period over a given location; and general floods, caused by precipitation over a longer time period



and over a given river basin. Of all the natural hazards addressed by FEMA, flooding seems to have the largest impact. Flooding causes more damage in the United States than any other severe weather related event, an average of \$5 billion a year.

There are several factors that worsen the impacts of flooding. They include: excessive amounts of impermeable surfaces; steeply sloped watersheds; constrictions such as grading or filling in the floodplain; obstructions such as bridges or culverts; debris from the watershed which can be carried by flood waters; contamination including soil, oil, fertilizer, animal waste, and untreated sewage; soil saturation following extended periods of precipitation; and flood velocity.

Flood events are usually described according to their probability of occurrence. Historical data has been used to determine the rainfall depth and intensity that signify storms of different return periods: 2-year, 10-year, 25-year, 50-year, 100-year, and 500-year. A 100-year flood will occur, on average, once every 100 years. It is possible to have more than one 100-year floods in the same year or even 100-year floods in successive years. The 100-year flood is often used to define flood-prone areas, and floodplain mapping is typically based on the 100-year flood. Additionally, most flood-related structures such as dams are designed to meet 100-year flood conditions.

The Town of Knightdale participates in the National Flood Insurance Program (NFIP). NCEM defines the NFIP in the following terms: "Administered by the Federal Insurance Administration, the National Flood Insurance Program makes federally subsidized flood insurance available to property owners in communities that participate in the program. Participating communities must adopt and enforce floodplain management ordinances that meet the criteria established by FEMA". FEMA conducts Flood Insurance Studies (FISs) that incorporate historical flood data and known flooding problems to determine flood hazards. These hazards are mapped on Flood Insurance Rate Maps (FIRMs). FIRMs are available for the entire jurisdictional area of Knightdale. Flood data from these maps appears on Map B-3, All Hazards Map, in Appendix B.

Floodplain areas are categorized on the Flood Insurance Rate Maps (FIRMs) as described in Table A-8 on the following page.



Table A-8 - Description of Floodplain Areas by Zone

Zone A	The 100-year or base floodplain. There are 6 types of A zones:	
	A	The base floodplain mapped by approximate methods, i.e., Base Flood Elevations (BFEs), are not determined. This is often called an un-numbered A zone or an approximate A zone.
	A1-30	These are known as numbered A zones (e.g. A7 or A14). This is the base floodplain where the FIRM shows a BFE (old format).
	AE	The base floodplain where base flood elevations are provided. AE zones are now used on new format FIRMs instead of A1-A30 zones.
	AO	The base floodplain with sheet flow, ponding, or shallow flooding. Base flood depths (feet above ground) are provided.
	AH	Shallow flooding base floodplain. BFEs are provided.
	A99	Area to be protected from base flood by levees or Federal flood protection systems under construction. BFEs are not determined.
Zone V and VE	AR	The base floodplain that results from the de-certification of a previously accredited flood protection system that is in the process of being restored to provide a 100-year or greater level of protection.
	V	The coastal area subject to a velocity hazard (wave action) where BFEs are not determined on the FIRM.
	VE	The coastal area subject to a velocity hazard (wave action) where BFEs are provided on the FIRM.
Zone B and Zone X	Areas of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods. B zones are also used to designate base floodplains of lesser hazards, such as areas protected by levees from the 100-year flood, or shallow flooding areas with average depths of less than 1 foot or drainage areas less than 1 square mile.	
Zone C and Zone X	Area of minimal flood hazard, usually depicted on FIRMs as exceeding the 500-year flood level. Zone C may have ponding and local drainage problems that do not warrant a detailed study or designation as base floodplain. Zone X is the area determined to be outside the 500-year flood.	
Zone D	Area of undetermined but possible flood hazards.	

Source: Keeping Natural Hazards From Becoming Disasters, A Mitigation Planning Guidebook for Local Governments, NCEM, 2003.



Review of historical data from NCDC showed that Wake County has experienced 51 flooding events since January 1, 1999. The majority of these events were flash floods as opposed to general floods. Countywide flooding was noted for nine (9) of the 51 flood events. The most severe general flooding that has occurred in the vicinity of Knightdale was due to Hurricane Floyd in 1999. The slow-moving hurricane dumped significant precipitation over the entire Eastern portion of North Carolina, causing general flooding from the Piedmont to the coast. NCDC data quantifies property damage due to flooding at \$250 million during this time period.

FEMA keeps records of structures that are frequently impacted by flooding. These structures are called repetitive loss structures. Repetitive loss structures have suffered flood damage on two or more occasions over a 10-year period ending on the date when a second claim is made, in which the cost to repair the flood damage, on average, equals or exceeds 25% of the market-value of the structure at the time of each flood loss event. A repetitive loss structure is important to the NFIP, since structures that flood frequently put a strain on the flood insurance fund. A review of FEMA data for Knightdale shows that there are no repetitive loss structures within the Town's jurisdiction.

NCEM has characterized the vulnerability to flooding in Wake County as highly likely. Historical data shows that flooding has occurred in Knightdale, the most severe associated with Hurricane Floyd in 1999. The Hurricane Floyd flooding event was listed as countywide with the most recent countywide flooding recorded on June 14, 2006. There are no flooding events listed as specific to Knightdale; however, the likelihood of occurrence is characterized as likely.

Flooding would not impact a large portion of the Town of Knightdale. Knightdale's current Unified Development Ordinance limits development within the floodplain and requires any residential or commercial structure to be elevated to at least two (2) feet above the freeboard level. This limits losses due to flooding, and therefore the impact due to flooding is characterized as mild.

Flooding would result in some damages, though critical facilities are not expected to be impacted for more than a week. None of the Town's critical structures are located within the floodplain. Damage to property is not expected to affect more



than 25% of the Town's land area. As a result, the level of impact is categorized as limited.

Based on probability of occurrence, magnitude, and level of impact, the hazard ranking of flooding is moderate. Flooding is a natural hazard whose impacts have been mitigated with some success through development ordinances, buyouts, and other programs. Flooding is addressed in the Hazard Mitigation Plan.

5. Hurricanes and Coastal Storms

According to NCEM, hurricanes are cyclonic storms that originate in tropical ocean waters. Hurricanes that impact North Carolina form in the so-called Atlantic Basin, from the west coast of Africa westward into the Caribbean Sea and Gulf of Mexico. They generally form between June 1 and November 30, with a peak around mid-September. A weather system with winds at or exceeding 39 mph is designated as a tropical storm, which is given a name and closely monitored by the NOAA National Hurricane Center in Miami, Florida. When winds are at or exceed 74 mph, the tropical storm is upgraded to hurricane status.

Hurricane intensity is measured using the Saffir-Simpson Scale, shown below. This scale categorizes hurricane intensity based on maximum sustained winds, minimum barometric pressure and storm surge potential. Heavy rainfall is not one of the criteria for categorizing the storms. The highest-category hurricane to affect Wake County was Hurricane Fran in 1995 which was a category 3.



Table A-9 - Saffir-Simpson Scale

Saffir-Simpson Category	Maximum sustained wind speed			Minimum surface pressure	Storm surge	
	mph	meters/ sec	knots	Millibars (mb)	feet	meters
1	74-96	33-42	64-83	Greater than 980	3-5	1.0-1.7
2	97-111	43-49	84-96	979-965	6-8	1.8-2.6
3	112-131	50-58	97-113	964-945	9-12	2.7-3.8
4	132-155	59-69	114-135	944-920	13-18	3.9-5.6
5	156+	70+	136+	Less than 920	19+	5.7+

Source: Keeping Natural Hazards From Becoming Disasters, A Mitigation Planning Guidebook for Local Governments, NCEM, 2003.

The damage incurred as a result of hurricanes has been well documented. The table on the following page shows hurricane damage by Saffir-Simpson category.



Table A-10 - Hurricane Damage by Category

Cat.	Level	Description	Example
1	MINIMAL	Damage primarily to shrubbery, trees, foliage, and unanchored homes. No real damage to other structures	Hurricane Jerry (1989)
2	MODERATE	Considerable damage to shrubbery and tree foliage; some trees blown down. Major damage to exposed mobile homes. Some damage to roofing materials of buildings; some window and door damage. No major damage to buildings.	Hurricane Bob (1991)
3	EXTENSIVE	Foliage torn from trees; large trees blown down. Some damage to roofing materials of buildings; some window and door damage. Some structural damage to small buildings. Mobile homes destroyed	Hurricane Gloria (1985)
4	EXTREME	Shrubs and trees blown down; all signs down. Extensive damage to roofing materials, windows and doors. Complete failure of roofs on many small residences. Complete destruction of mobile homes	Hurricane Andrew (1992)
5	CATASTROPHIC	Shrubs and trees blown down; considerable damage to roofs of buildings; all signs down. Very severe and extensive damage to windows and doors. Complete failure of roofs on many residences and industrial buildings. Extensive shattering of glass in windows and doors. Some complete building failures. Small buildings overturned or blown away. Complete destruction of mobile homes.	Hurricane Camille (1969)

Source: Keeping Natural Hazards From Becoming Disasters, A Mitigation Planning Guidebook for Local Governments, NCEM, 2003.

Although the coast is at greater risk for damage from hurricanes, inland areas such as Knightdale have felt the effects of hurricanes, too. Recent historical data obtained from NCDC shows that 3 hurricanes have hit Wake County in the past 10 years. Hurricanes, Dennis and Floyd hit in 1999, followed by Isabel in 2003. Data for damages caused by these storms follows:



Table A-11 - Hurricane Damage Data

Name	Date	Description
Dennis	9/4/1999	Category 2 6-8 inches of rain in Triangle Never hit coast of NC
Floyd	9/15/1999	Category 2 15-20 inches of rain in Eastern NC 21 deaths in Central NC Livestock losses, infrastructure damage Widespread flooding 3 rd costliest hurricane in US 20 th deadliest hurricane in US (56 deaths)
Isabel	9/18/2003	Category 2 40 deaths Considerable damage on NC coast Widespread power outages \$7.3 million in property damage

NCEM has characterized the probability of occurrence of a hurricane in Wake County as low, but review of hurricane data indicates that hurricanes have impacted Wake County numerous times within the past decade. According to a review of NCDC hurricane data, hurricanes have affected Knightdale and are expected to continue to do so. The occurrence of a hurricane is categorized as likely.

High winds associated with a hurricane could result in moderate damage to Knightdale. Flooding is not as much of an issue since the majority of development is not within the floodplain. As a result, the magnitude or intensity of damage is categorized as moderate.

A hurricane could impact as much as 25% of the town and result in some injuries and property damage and the disruption of critical services for as much as a week. As a result, the level of impact is categorized as limited.

Based on probability of occurrence, magnitude, and level of impact, the hazard ranking of hurricanes/coastal storms is moderate. Hurricanes/coastal storms are addressed in the Hazard Mitigation Plan.

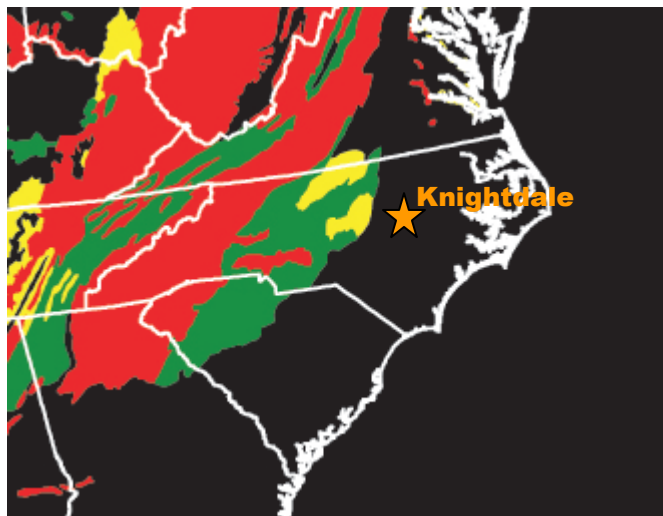


6. Landslides/Debris Flow

According to the United States Geological Survey (USGS), landslides and debris flows are major geologic hazards that occur in all 50 states, causing an average of \$3.5 billion (2005 dollars) in damages and resulting in an average of more than 25 – 50 fatalities each year. Landslides are especially troubling because they often occur with other natural hazards, such as earthquakes, volcanoes and floods. In the eastern United States, landslides are common throughout the mountainous Appalachian region and New England, predominantly from sliding of clay-rich soils.

The USGS identifies landslide incidence/susceptibility for the eastern United States by (1) classifying geographic areas by high, medium, or low landslide incidence and (2) evaluating geologic formations in these areas by high, medium, or low susceptibility to landsliding. Susceptibility to landsliding is defined by the USGS as the probable degree of response of geologic formations to natural or artificial cutting, loading of slopes, or to unusually high precipitation. Generally, it is assumed that unusually high precipitation or changes in existing conditions can initiate landslide movement in areas where rocks and soils have experienced numerous landslides in the past.

NCEM has characterized the vulnerability to landslides in Wake County as low as evidenced by the adjacent graphic from the USGS. Although North Carolina has experienced landslides, they have occurred in the mountainous region of the state. There have been no reported landslides in Wake County or Knightdale. The occurrence of a landslide is characterized as unlikely.



A landslide in Knightdale could result in little damage to the entire Town. As a result, the magnitude or intensity of damage is categorized as mild.



A landslide in Knightdale would likely affect the only a small portion of the Town and result in minor injuries, minor damages to property and no disruption of critical services. As a result, the level of impact is categorized as negligible.

Based on probability of occurrence, magnitude, and level of impact, the hazard ranking of landslide is very low. Landslides are not addressed in the Hazard Mitigation Plan.

7. Tornadoes/Severe Thunderstorms

According to the National Weather Service, a severe thunderstorm is a thunderstorm that produces tornadoes, hail 0.75 inches or more in diameter, or winds of 50 knots (58 mph) or more. The identification and assessment of tornadoes as a natural hazard cannot be fully addressed without addressing severe thunderstorms also. Severe thunderstorms are frequent occurrences in North Carolina. NCDC data for Wake County shows that 120 severe thunderstorms have been reported in the last decade since January 1, 1999. These thunderstorms resulted in a combined total of 8 injuries, \$316 thousand in property damage, and \$5,000 in crop damage. Of the 120 storms, 114 affected other communities in Wake County, and the remaining six (6) were categorized as affecting not just Knightdale, but all of Wake County. Hail in excess of 0.75 inches diameter was reported 119 times in Wake County, five (5) of those times occurring in Knightdale in the same time period. The damages caused by severe thunderstorms are minimal in comparison with other natural hazards, but the fact that tornadoes are frequently spawned by severe thunderstorms increases the potential damage due to the storms.

The National Weather Service defines a tornado as a violently rotating column of air in contact with the ground and extending from the base of a thunderstorm. A condensation funnel *does not need to reach to the ground* for a tornado to be present; a debris cloud beneath a thunderstorm is all that is needed to confirm the presence of a tornado, even without a condensation funnel.

The intensity, path length and width of tornadoes are rated according to a scale developed by T. Theodore Fujita and Allen D. Pearson. Tornadoes classified as F0-F1 are considered weak tornadoes, those classified as F2-F3 are considered strong, while those classified as F4-F5 are considered violent.



Table A-12 - Fujita-Pearson Tornado Scale

F-Scale	Damage	Winds (mph)	Path Length (miles)	Mean Width (miles)
F0	Light	40-72	<1	<0.01
F1	Moderate	73-112	1-3.1	0.01-0.03
F2	Considerable	113-157	3.2-9.9	0.04-0.09
F3	Severe	158-206	10-31	0.1-0.31
F4	Devastating	207-260	32-99	0.32-0.99
F5	Incredible	261-318	100	1.0
F6	Inconceivable	319-379	Unknown	Unknown

Source: Keeping Natural Hazards From Becoming Disasters, A Mitigation Planning Guidebook for Local Governments, NCEM, 2003.

Review of NCDC Data since January 1, 1999 indicates that three (3) tornadoes have been reported in Wake County during that time period, and none of them affected Knightdale. All three (3) were classified as F0. No crop damage was reported due to tornadoes.

According to NCEM, tornado potential for Wake County is characterized as high. The likelihood of occurrence for tornadoes/severe thunderstorms is classified as likely.

Historically, the majority of tornadoes in Wake County have been classified as weak (F0 or F1). Only one (1) F4 tornado has ever occurred in Wake County since records have been kept (November, 1988), and it resulted in two (2) deaths, 105 injuries and \$250 million in property damage. Therefore, the type of tornado expected to hit Knightdale in the future is F0 or F1. A F0 or F1 tornado would result in limited damage to Knightdale. Path lengths for F0 and F1 tornadoes are typically less than 3 miles, and the mean width does not exceed 0.03 miles. The magnitude of damage for a weak tornado would be characterized as mild.



Likewise, hail and wind damage from severe thunderstorms would be characterized as mild.

Tornadoes/severe thunderstorms have the potential to have some substantial impacts, resulting in damages property, injuries, and the possible shutdown of critical facilities. As a result, the level of impact is categorized as limited.

Based on probability of occurrence, magnitude, and level of impact, the hazard ranking of tornadoes/severe thunderstorms is moderate. Tornadoes/severe thunderstorms are addressed by the Hazard Mitigation Plan.

8. Wildfires

A wildfire is an uncontrolled burning of grasslands, brush or woodlands. The potential for wildfire depends upon surface fuel characteristics, recent climate conditions, current meteorological conditions and fire behavior. Hot, dry summers and dry vegetation increase susceptibility to fire in the fall, a particularly dangerous time of year for wildfire.

As development has spread into areas which were previously rural, new residents have been relatively unaware of the hazards posed by wildfires and have used highly flammable material for constructing buildings. This has not only increased the threat of loss of life and property, but has also resulted in a greater population of people less prepared to cope with wildfire hazards.

In North Carolina, wildfire potential has been assessed using state Forest Service records for the period 1950-1993. According to NCEM, wildfire potential for Wake County is characterized as moderate. Historical data shows that only 6 13 wildfires were reported in North Carolina since 1993, and none of those were in Wake County. However, it should be noted that seven (7) of those 13 wildfires have now occurred within the last two (2) years, which may suggest a correlation to the most recent state-wide drought. Nonetheless, the occurrence of a wildfire is categorized as unlikely.

A wildfire in Knightdale would likely result in damage to the limited areas of the Town. As a result, the magnitude or intensity of damage is categorized as mild.



A wildfire in Knightdale would likely affect less than 10% of the Town. Neither loss of life nor disruption of critical services would be expected. As a result, the level of impact is categorized as negligible.

Based on probability of occurrence, magnitude, and level of impact, the hazard ranking of a wildfire is very low. Wildfires are not addressed by the Hazard Mitigation Plan.

9. Severe Winter Weather

Severe winter storms can result in several hazardous weather conditions, including heavy snow, blizzards, freezing rain, sleet and extreme cold. The entire state of North Carolina has a likelihood of experiencing severe winter weather. In the Piedmont, cold air damming contributes to freezing rain and ice storm events. These events occur at least as often as moderate or severe snow events in this region. According to reports by Gail Hartfield of NWS, cold air damming occurs when a thin layer of cold air becomes trapped against the eastern slopes of the Appalachian Mountains. Warmer air lies above the cold air, and when precipitation falls through both layers, freezing rain and sleet result.

The most frequent impacts from severe winter storms are power outages and impassable roads. Trees, downed due to the weight of ice and snow, contribute to both of these impacts. Falling trees and limbs result in property damage, downed power lines, and impassable roads.

Severe winter weather is given a moderate level of vulnerability by the NCEM. Review of NCDC data shows that 18 snow and ice events have been reported in Wake County since Jan 1999. 14 were characterized as "winter storms", three (3) as "winter weather" and one (1) as "heavy snow". No data on property damage, loss of life, or structural damage was noted in the NCDC reports. As a result, the occurrence of a severe winter storm is categorized as likely.

A severe winter storm in Knightdale would likely result in property damage to limited areas of the Town. As a result, the magnitude or intensity of damage is categorized as mild.

A severe winter storm in Knightdale could likely affect 10% of the Town. Disruption of critical services for over 24 hours would be possible, particularly if



power outages are widespread or ice accumulation on roads leads to traffic gridlock and blocked arterials as occurred with the winter weather event of 12/26/2004. As a result, the level of impact is categorized as limited.

Based on probability of occurrence, magnitude, and level of impact, the hazard ranking of severe winter storm is moderate. Severe winter weather is addressed in the Hazard Mitigation Plan.

